

NASA TECHNICAL TRANSLATION

NASA TT F-14436

LIFE SUPPORT SYSTEMS FOR SPACECRAFT

G. Voronin, A. Polivoda and Ye. Vinogradov

(NASA-TT-F-14436) LIFE SUPPORT SYSTEMS OF
SPACECRAFT G. Voronin, et al (NASA) Jan.
1972 15 p CSCL CCK

N73-10155

Unclass

G3/05 46398

Translation of "Sistemy zhizneobespecheniya kos-
micheskikh korabley", Aviatsiya i Kosmonavtika
(Aviation and Astronautics), Vol. 9, 1966,
pp. 44-47.

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 JUNE 1972

Системы жизнеобеспечения
Космических Кораблей,

Voronin, G., et. al.

PROFESSOR G. I. VORONIN, Sc.D (TECHNICAL SCIENCES)

A. I. POLIVODA, CANDIDATE OF BIOLOGICAL SCIENCES

YE. VINOGRADOV, ENGINEER

"Life Support Systems of Space Craft"

The flights of single-seater and multi-seater piloted space crafts poses a problem of development of technical means for a long-term life support of man and the conservation of his efficiency and normal state of feeling. Specific conditions of cosmic flights and the limited useful weight of a space craft necessitate such rigid demands applied to the life support systems, as the minimum permissible size, volume and weight of the system, its small energy consumption, the minimal heat circulation through the system and maximal reliability.

During cosmic flights men consume as much oxygen, water, and food as under the normal conditions on the earth and in addition, liberate the products of their activity (carbon dioxide, volatile products of material exchange, liquid and solid excrements, etc.). In the majority of cases the disposal of carbon dioxide and other products liberated by man into the cosmos is not permitted. It is also necessary to prevent the contamination of a space craft cabin which may be

very small (of the order of few cubic meters). In this case, naturally, the most significant problem is the maintenance of such physical parameters as the purity of air, the constant composition of gas, pressure and temperature, i.e., a problem of conditioning the cabin atmosphere.

The maintenance of the optimum earth physical conditions (an atmosphere consisting of nitrogen-oxygen gas mixture, 760mm Hg. pressure, 30% relative humidity, and + 20°C temperature) suitable for human activities in a space craft cabin of a few m³ in volume is connected with large energy losses in a life-support system. Positively, this system imitating the earth conditions will be a complex and heavy combination consisting of mechanical, electro mechanical, and electronic devices which in their turn consists of a large number of smaller parts.

Let us investigate few types of life support systems of space craft.

A Supply System

A system of this type rigidly evaluates the necessary supply of material consumed by man and their supply is not restored as far as it is consumed. The weight of such a system is the sum of weights of aggregates and material supply necessary for consumption by man. It

is known that a man of 70 kg in weight consumes per day on the average, 600 lbs. of oxygen, 2.3 kg of water, 0.6 - 0.7 kg of food material (100 - 150 g. of albumin, 70-90 g. of fat, 420 - 500 g. of hydro carbons).

The weight of all food materials, counting liquids, is 2.0 - 2.5 kg, i.e., $\frac{2}{3}$ of its weight is water. Thus $\frac{4}{5}$ of the 5.5 kg. allowance is water.

In order of achieving the minimum sizes and volumes and consequently, the minimum weights, various methods are used to guarantee sufficient supply. For example, the supply of oxygen is produced by three basic methods; in balloons, under 500 - 700 atm compression; in gasifiers, as liquid or solid material at low temperatures; and as a chemically bound state in overperoxide compounds or hydrogen peroxide H_2O_2 .

Without detailed discussion of strong and weak points of these systems, it may be pointed out that the overperoxide systems are more convenient to apply. They are simple to construct and are reliable in exploitation absorbing carbon dioxide simultaneously with the liberation of oxygen and, moreover, do not demand a heavy chemical absorber of carbon dioxide necessary in utilization of pure oxygen supply.

System of this type require an electrical system of a few tens watt power to be used for driving the aggregates necessary for conditioning the cabin atmosphere.

This circumstance coupled with its simplicity and reliability are the basic merits of the supply system.

Regenerated Physico-chemical System

In a system of this type the material components consumed by man during his active life process (oxygen and water) are partly regenerated. But, in contrast to the supply system, the regeneration system consumes considerable amount of external energy.

A physico-chemical regenerator of water is lighter than an air regenerator and consumes a relatively small power, therefore the weight characteristics and energy consumption of the whole system are practically determined by energy consumption and air regenerator characteristics.

The physico-chemical systems, as well as the supply ones cannot guarantee the total preservations of all food components on account of some deficiencies present in the methods of drying and storing. The utilization of natural canned products is unexpedient because of weight limitations.

Thus the physico-chemical regeneration systems are even more complicated than the supply ones. Neither of these systems is completely suitable for long-term flights.

However, the expediency of these systems does not disappear since some of them can be utilized partly or wholly as the emergency systems (the supply system, for example) for the solution of problems of life support in

long-term flights. In addition, some elements of these systems may be an integral part of systems with biosynthesis which are investigated below.

Biosynthetic Systems

Biosynthetic systems directly utilizing Solar energy in plant photosynthesis, a principle on which is based the system regeneration, may be considered as the most promising systems for a support of life activities of space craft crews. The promising character of this system type was already discussed by K. Ye. Tsiolkovskiy. The utilization of these systems permits, in principle, the solution of oxygen regeneration problem and the removal of carbon dioxide from the system atmosphere.

The necessity of the application of a solar energy apparatus for oxygen regeneration or for the utilization of additional energy from the photon or corpuscular irradiation disappears and the problem of regeneration of liquid and solid food materials from waste is solved.

One of the merits of biosynthetic system is their high efficiency coefficients which are determined by the high energetic efficiency of photo-synthesis (it is considerably higher than in the most advanced batteries employed in the regenerators). This permits a reduction in the flow of thermal energy through the system and considerably decreases its weight and simplifies its construction.

Even a brief enumeration of the merits of life-support² biosynthetic systems gives a good indication of their promise.

A completely closed bioenergetic system i.e., a complete circulation system, seems to be the most desirable; but its development is, in principle, not feasible. The complete material circulation is absent even on the earth because several materials leave the circulation at its various stages as the inert mass. A simple imitation of the earth system with its higher type animals and lower plants, by taking into consideration the limited weight, shape and energy consumption, is practically not feasible on account of a small, total efficiency coefficient of the proposed system.

Therefore in designing the weight and energy approach coupled with some degree of closed circulation cycle are recommended. In this system the regeneration of oxygen, water and then food first should be taken care of. In addition, it is necessary to solve a problem of biological compatibility of the system links. Micro quantities of nitrogen, sulfur, phosphorous and other elements leaving the circulation system, should be more expediently restored from the supplies stored aboard a space ship. From a technical point of view it is desirable to have fewer types of the uniform biological composition for the development of simple and reliable life-supporting biosynthetic systems. An increase in the number of men aboard

a space ship does not lead in principle, to a system change, but proportionally increases its weight and its energy consumption. The optimum number of biological species (i.e., the minimum number but sufficient for the balanced work) is determined by the expected duration of the working system. A working system which is expected to last for a few years should have only the one basic biological species, an autotroph. This is an unicellar photo-synthetic microalga whose biomass contains a set of vitamins and amino-acids necessary for men and therefore can be used for feeding.

For long-term cosmic voyages the following system can be suggested: an automatic cultivator of unicellar organisms, algae and chemosynthetics included, a link of biomass reprocessing, a gas-liquid mineralized of the products of man activity, also a temporary storage of organic waste-sanitary service volume. This system, in addition, will include a generator of ozon, carbon oxide concentrator and a physico-chemical generator of drinking water containing service volumes for clean and polluted water.

The photo-synthetic circuit of the system under investigation consists of a section of radiators of the automatic cultivator of unicellar photo-synthetic algae (thermo-philous photo resistant strain of chlorella in our case) which is carried beyond the cabin limits. This arrangement permits the limitation of the additional

solar energy which may be introduced into the ship interior and, moreover, simplifies a system of light flux regulation, the flux irradiating the radiators. A suspension, i.e., the alga cells surrounded by a definite feeding medium, circulates through the radiators where the total radiator area selected to be 1.5 - 2.0 times greater than it is necessary for the normal atmospheric regeneration.

This increases the reliability of the system. The general pipeline outlet of radiators delivers the alga suspension to a gas-exchanger where it releases O_2 and is saturated with CO_2 . The pipeline outlet is connected with an inlet of the regenerating circuit of feeding medium where a part of alga suspension goes to from the photo synthetic circuit.

A circuit of regeneration of feeding medium marked for the support of nominal composition of feeding medium in the photo synthetic circuit may consist of an aggregate for the separation of cellular biomass from the system suspension where the products of material exchange are removed and the impoverished feeding medium is conducted to the second aggregate where it is regenerated, i.e., being enriched with mineral substances and water. Finally the feeding medium enters the photo synthetic circuit.

Water regeneration circuit recovers water from the products of exchange material in an "inhabitant" and transforms it into the standardized water. The principal

units of this circuit can be a water separator (by using multistaged evaporation and concentration) electro-chemical filters, absorbers, catalizers, etc.

A circuit of solid substances guarantees the "inhabitant" to have necessary combination of protein, hydrocarbons, vitamins and lipids. All the substances go to a kitchen where they acquire the corresponding external appearance, palatability, consistency, etc.

In addition, the mineralization of the substance exchange products of an "inhabitant", after their reprocessing in a water-separation block, takes place in this circuit. From the circuit, the products go into the mineralization chain from where they are moving in sufficient quantity into the circuit of feeding medium regeneration. An emergency system of physico-chemical regeneration which gets its supply of energy from the solar batteries, as an example, is also taken into consideration.

The most actual problem here remains the development of an air regeneration system where such a bio object as the photo synthetic micro algae will be utilized as the principal link. It is quite evident that the processes taking place in the bio object, as well as in the whole system of air regeneration, should be controlled. The development of a system of automatic control for such a purpose as the control of biologic air regeneration is

exceptionally complicated and many causes are responsible for it. At first, it is necessary, using biological investigations, to discover the parameters which better reflect the state of a regulated object and to establish some regularities present in the processes under study; secondly, some information pertaining to these parameters and expressed in electric signals is necessary; and finally there is the necessity to have the controlling instructions for an executive device of an automatic regulation system supporting the air-regeneration process under optimum conditions.

The population growth of chlorella cells, or any other micro alga species, is connected with the biosynthetic processes and with an increase in the potential energies of chemical bonds of cell substrata. To measure the intensity of bio-synthesis of cell population and to control this process it is necessary to have the data pertaining to the cell photo-synthesis, geometrical volume changes, the rate of gas exchange; the energies of after-illumination, oxygen cell generation, the values of thermal losses, the intensity of separation of macro and trace elements from the cultivated medium.

Let us briefly list the principal parameters which determine the state of a bio object in the circuit of biological air regeneration (b.a.r) of life-support system

and let us examine the ways of obtaining some information pertaining to these parameters and expressed in electric signals.

In our system the following parameters were accepted: the amount of chlorella cells and their distribution, with respect to size, in suspensions; integral culture density; an index of the culture photo synthesis; the formation of oxygen by the culture; the concentration level of hydrogen ions in the medium; and the suspension temperature.

The number of the chlorella cells and their distribution, (with respect to size) in the suspension are determined using the channel of a discrete counter.

A transducer utilized in this system is characterized by the fact that the amplitude of an electric signal formed by a discrete cell in passing through the transducer is proportional to the cell volume.

The density of culture is determined with the help of an optical transducer by passing the luminous flux through an area with transparent walls where the chlorilla suspension is circulated and by registering the passing luminous flux with a photo electric circuit.

The electric signal of this transducer will be proportional to the optical density of suspension, i.e., to the rate of biomass growth. This signal is amplified

and formed, and the information is presented as a pulse series coded in a definite manner.

The principal elements of a system which registers the photo synthesis intensities are: a helio transducer of culture illumination by the sunlight and a transducer for the registration of after illumination which consists of an optical system, a photo multiplier, and an amplifying and pulse-forming circuits.

An information of the same importance, and pertaining to the state of a photo synthetic culture apparatus, is found in the data of a special oxygen transducer, an indicator of dissolved oxygen in the channel suspension.

This information is analyzed jointly with the data obtained by a transducer after illumination, a method permitting the evaluation of photo synthetic abilities.

The optimum cultivation of bio objects (chlorella, in particular), is based on maintaining the concentration of hydrogen ions in a suspension at some given level (pH) the suspension depending in its turn on the composition and the concentration of macro and trace elements of mineral supply.

In addition, the absorption intensity of the most important elements of mineral nourishment, including the ions of alkali metals, can serve as one of the significant characteristics of the chlorella activity. Thus, it is

clear that by measuring the concentration of hydrogen ions and other elements we are partially able to judge the chlorella activity and, by controlling their number in their habitation medium, the composition and concentration of nutritional elements under given optimum limits can be maintained.

One of the most significant indexes of bio object cultivation is the temperature of suspension. In order to maintain a certain given in advance temperature in a system under investigation, an apparatus of automatic temperature stabilization is utilized.

All the information channels enumerated by us give some extent a reliable picture of the bio object condition.

The basic functional purpose of a bio system is the regeneration of the atmosphere of a habitable cabin. This system absorbs carbon dioxide liberated by the man and liberate oxygen which is necessary for the normal activity.

In the preceding pages we have discussed the first group of information channels. They give a picture of the activity of the cell population on the basis of which the cultivation process for maintaining the optimum conditions of air regeneration can be controlled.

The transducers of the second group control the air regeneration process. This group of channels give to the control system the data pertaining to the atmospheric

pressure, humidity and temperature conditions and the presence of harmful admixture in the cabin.

The enumerated information systems are utilized at present. The composition of an atmosphere, for example, can be controlled by the gas analyzers. The transducers for the control of other cabin parameters are well known.

Each parameter characterizes the bio object state but gives an incomplete information. The most complete information pertaining to a bio object condition can be obtained only by using a complex data treatment.

In the memory each computing apparatus are embedded the optimum values of each parameter and the generalized optimum object condition.

The current information is compared with the embedded one and on the basis of the analysis of deviations of given parameters from the actual ones, the computing apparatus produces a series of commands leading to the process of a given value.

A brief review of publications shows that the development of life-support systems for long-term space craft flights is one of the fundamental problems of present cosmic navigation.